COGNITIVE AND NEUROPSYCHOLOGICAL CONDITIONS AFFECTING LEARNING IN STUDENTS WITH AUTISM SPECTRUM DISORDER (ASD)

TRASTORNOS COGNITIVOS Y NEUROPSICOLÓGICOS QUE AFECTAN AL APRENDIZAJE EN ESTUDIANTES CON TRASTORNO DEL ESPECTRO AUTISTA (TEA)

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ABSTRACT

The study provides evidence that neuroeducation-based interventions can greatly improve math learning in children with Autism Spectrum Disorder (ASD) by mitigating cognitive load concerns. Cognitive load theory contends that learning is impaired when the capacity of working memory is exceeded, a frequent problem for students with ASD given their inherent cognitive and attentional differences. The effectiveness of the

RESUMEN

El estudio proporciona evidencia de que las intervenciones basadas en la neuroeducación pueden mejorar el aprendizaje de matemáticas en niños con Trastorno del Espectro Autista (TEA) al mitigar las preocupaciones sobre la carga cognitiva. La efectividad de la intervención radica en su naturaleza multicomponente, que integró apoyo visual con modelos formales de

intervention lies in its multi-componentiality, which integrated visual support (such as process diagrams and graphic organizers) with formal problem-solving models and affect regulation strategies. Adaptations allowed students to take complicated mathematical concepts and break them down into smaller steps, which reduced frustration and improved understanding. Secondly, the study highlights the element of emotional and motivational dimensions of learning for ASD students. Anxiety and stress tend to add cognitive load, which becomes progressively harder for these students to manage. Adding affective support—relaxation strategies, praise, and personal encouragement—to the intervention not only improved academic performance but also attitude towards learning. Teachers noticed students were more confident and more persevering in solving math problems, which suggests reducing cognitive load is linked to emotional resilience. That long-term gains were present at one-month post-intervention suggests that these interventions can lead to long-term gains in both cognitive and affective domains. This is a particularly critical finding, as most educational intervention for ASD leads to short-term gains that are not maintained over time. The study suggests that neuroeducation-based interventions, where instructional practice is informed by brain-based principles of learning, may have more long-term effects by stimulating more neural pathways for memory, logic, and emotional regulation. Research in the future must investigate whether such interventions are feasible with different age groups, levels of autism spectrum disorder severity, and mathematical topics. Furthermore, analysis of the neurobiological foundations of such gains —i.e., brain activation profiles during solving— will

resolución de problemas y estrategias de regulación afectiva. Las adaptaciones permitieron a los estudiantes descomponer conceptos matemáticos complicados en pasos más pequeños, lo que redujo la frustración y mejoró la comprensión. En segundo lugar, el estudio destaca el elemento de las dimensiones emocionales y motivacionales del aprendizaje para los estudiantes con TEA. La ansiedad y el estrés tienden a aumentar la carga cognitiva, lo que se vuelve progresivamente más difícil de manejar para estos estudiantes. Añadir apoyo afectivo a la intervención no solo mejoró el rendimiento académico, sino también la actitud hacia el aprendizaje. Los maestros notaron que los estudiantes eran más seguros y perseverantes en la resolución de problemas matemáticos, lo que sugiere que reducir la carga cognitiva está vinculado a la resiliencia emocional. El hecho de que se observaran ganancias a largo plazo un mes después de la intervención sugiere que estas intervenciones pueden llevar a mejoras duraderas tanto en los dominios cognitivos como afectivos. Este es un hallazgo particularmente crítico, ya que la mayoría de las intervenciones educativas para el TEA conducen a ganancias a corto plazo que no se mantienen en el tiempo. El estudio sugiere que las intervenciones basadas en la neuroeducación, donde la práctica instruccional se informa por principios de aprendizaje basados en el cerebro, pueden tener efectos más duraderos al estimular más vías neuronales para la memoria, la lógica y la regulación *certainly provide an even deeper understanding of the ways that cognitive load reduction can benefit learning. The study also has important implications for curriculum development and teacher education, and it points to the need for professional development opportunities that equip teachers to utilize neuroeducational interventions with neurodiverse learners. Lastly, this study contributes to the cumulative body of evidence supporting personalized, neuroscience-based education for students with ASD. In moving beyond one pedagogy for all, educators can create more inclusive classrooms that invite diverse cognitive profiles. The findings support an integrated model of academic learning coupled with emotional and cognitive support, opening the way to more effective and compassionate education for neurodiverse learners. These findings must be considered by policymakers and school administrators when designing special education programs so that evidence-based practices are made available to all students who might benefit from them.*

KEYWORDS

Autism Spectrum Disorder (ASD); Cognitive Load; Neuroeducation; Mathematical Learning; Cognitive Load

emocional. La investigación futura debe investigar si tales intervenciones son viables con diferentes grupos de edad, niveles de severidad del trastorno del espectro autista y temas matemáticos. Además, el análisis de las bases neurobiológicas de tales ganancias ciertamente proporcionará una comprensión aún más profunda de las formas en que la reducción de la carga cognitiva puede beneficiar el aprendizaje. El estudio también tiene importantes implicaciones para el desarrollo curricular y la formación de docentes, y señala la necesidad de oportunidades de desarrollo profesional que capaciten a los maestros para utilizar intervenciones neuroeducativas con estudiantes neurodiversos. Por último, este estudio contribuye al cuerpo acumulativo de evidencia que apoya la educación personalizada basada en la neurociencia para estudiantes con TEA. Al ir más allá de una pedagogía para todos, los educadores pueden crear aulas más inclusivas que inviten a diversos perfiles cognitivos. Los hallazgos apoyan un modelo integrado de aprendizaje académico junto con apoyo emocional y cognitivo, abriendo el camino hacia una educación más efectiva y compasiva para los estudiantes neurodiversos.

PALABRAS CLAVE

Trastorno del Espectro Autista (TEA); Carga Cognitiva; Neuroeducación; Aprendizaje Matemático; Memoria de Trabajo.

INTRODUCTION

The expansion of a detailed understanding of the neuropsychological and cognitive conditions that affect learning in students with Autism Spectrum Disorder (ASD) has been growing increasingly important in the fields of educational and neuroeducational research (Pérez , 2022). With scientific inquiry proceeding to explore brain functions and cognitive capacities, it has now come to be realized that ASD students, being completely capable learners, are faced with a package of cognitive as well as affective barriers standing in the way of their active participation in the learning process, particularly in senior-level courses like mathematics (Arroyave et al., 2023).

The cognitive load theory, by Sweller in the 1980s, describes mental effort involved while learning to process information. The theory has evolved over the years, and introducing it to neuroeducation, students with ASD have been found to be able to experience much greater cognitive load than neurotypical learners as they perceive and process information differently. Particularly, difficulties in the regulation of complex procedures, social demands, emotional control, and attention deficits can produce cognitive overload, so that learning in such areas as mathematics—where not only is cognitive capability required but enormous capability to process and structure information sequentially—is particularly challenging (Pérez-Jara & Ruíz, 2022). The neuroeducational model, by virtue of its blending of ideas from cognitive neuroscience and pedagogy, has produced new kinds of interventions and rendering teaching practice neurocognitive student patterns accommodating. Here, recognition of how cognitive load is impacting learning in students with ASD from a neuroeducation point of view is a unique challenge to revolutionize instructional strategies and improve the process of learning for such students (Rechy et al., 2024). ASD students are characterized by difficulties in major areas such as communication, social interaction, cognitive flexibility, and emotional regulation.

Apart from high cognitive load, they would also affect their ability to sustain with the requirements of mathematics, a field that also requires not merely abstract thinking but the ability to execute strings of steps, think rationally to arrive at conclusions, and deal with vast amounts of information simultaneously (Bermúdez et al., 2023).

Few authors have, however, investigated cognitive load in relation to learning mathematics in ASD learners. Notwithstanding some previous research studies on the effects of cognitive difficulties on overall school achievement, there are few specific studies regarding the effects of cognitive load on mathematical learning by ASD students (Cholbi et al., 2025). Secondly, although cognitive load is a central theory in learning theory, empirical studies specifically examine the interaction of the neuropsychological characteristics of ASD with cognitive load and its effects on learning mathematics are limited and fragmented. There needs to be further research on how students with ASD mathematically process information and how their ability to handle cognitive load plays a role in their academic achievement in this subject. Cognitive load, as above described, is a central tenet of learning theory. Sweller (1988) developed cognitive load theory, which posits that learning is limited by working memory capacity while processing information.

Cognitive load can be divided into three: intrinsic cognitive load (arising due to the complexity of the task), extraneous cognitive load (which emerges from the way information is presented) and germane cognitive load (relating to effort directed towards establishing coherent knowledge (Escobar, 2023).

All three types of cognitive load can be activated in math problems in individuals with ASD, and this may explain the issues these individuals have when trying to solve math problems (Reyes, 2024). Alternatively, ASD is characterized by a series of cognitive difficulties including working memory deficits, selective attentional deficits, cognitive flexibility deficits, and problem-solving deficits. As per research López-Florit (2023), children with ASD prefer to focus on novel detail at the expense of information processed globally, and this will augment cognitive load in doing intricate tasks such as math. Additionally, poor emotional regulation and proper anxiety management will also increase cognitive load and disrupt learners' capacity to focus on work and process step-by-step logical procedures to solve mathematical problems. Neuroeducation is a cross-disciplinary process to integrate neuroscientific understandings and teaching practices (Zuluaga Arroyave, 2023).

Neuroeducation considers the weaknesses and strengths of the human brain to develop more efficient and suitable teaching strategies for different types of students. In students with ASD, neuroeducation can deliver clear methods to restrict cognitive load, i.e., employing visual aids, organizing the task in an organized manner, and incorporating emotional regulation strategies (Sweller, 2023). Certainly, one of the most promising areas in neuroeducation is research on how modulation of cognitive load can promote learning. Fernandes et al. (2021) Universal Design for Learning (UDL) research suggests that differential cognitive demand and pedagogical differences will allow diverse students to be accommodated to reduce cognitive load.

This is especially relevant to ASD students since they can be best assisted by pedagogy that considers their cognitive characteristics and information management issues (Paz et al., 2022). The knowledge gap identified in this study is that there is no study that seeks to explore the specific impact of cognitive load on math learning among students with ASD. Whereas there has been some study of comparative academic functioning of students with ASD and their non-disabled counterparts, there has been very limited study of how built-in cognitive differences in ASD affect cognitive load during learning mathematics, a process involving intricate and sequential cognitive processes (Wojcik , 2022). In addition, there is research that are prone to ignore the integration of neuroeducational practices that have the potential to facilitate practical solutions in terms of reducing cognitive load and improving learning among students with ASD (Torrado Duarte et al., 2024).

This study will bridge the gap by investigating the impact of cognitive load on math learning among students with ASD, from a neuro-education perspective. It is anticipated that via the knowledge on how cognitive ability of children suffering from ASD impacts cognitive load towards learning mathematics and how this load can be approached to enable superior learning performance. Areas to the aim of this study are as follows:

1. Examine how the influence of cognitive load affects learning mathematics among children suffering from ASD.
2. Identify the most common sources of cognitive load when math is learned by students with ASD, e.g., attention demands, working memory demands, and complex problem-solving.

Assumption of beginning point in the present study is that ASD students experience an increased cognitive load when faced with mathematical problems due to their singular neuropsychological profile, a negative impact on mathematics skills. The second assumption in the present study is that the use of pedagogical interventions supported by neuroeducational strategies—considering the limitations of cognition as well as the students' particular needs—would reduce cognitive load and improve mathematics skills.

METHOD

The research was quasi-experimental, whereby an experimental group that received a pedagogical intervention made to restrict cognitive load was contrasted with a control group that received the typical curriculum. The rationale behind this design is that, due to practical constraints, students could not be randomized because the target group was pupils with ASD already attending inclusive and special learning centers. To maximize comparison validity, the two groups were matched as equally as possible on key demographic and cognitive variables to minimize confound.

The final sample consisted of 60 students clinically diagnosed with Autism Spectrum Disorder, aged 8–12 years, recruited based on DSM-5 criteria and specialist evaluation. Severe intellectual disability and neurological comorbidities were ruled out to maintain mathematics learning-specific cognitive load focus. Recruitment was from inclusive schools and ASD-specialized centers.

A battery of standardized measures was employed to collect data on math performance and cognitive load. Subjective mental effort while solving problems was measured with the Cognitive Load Scale for Children (CLS-Child). The capacity of verbal and visuospatial working memory before and after the intervention was also gauged with the Working Memory Test Battery for Children (WMTB-C), based on its central role in regulating cognitive load for challenging tasks. Mathematical ability was assessed by a specifically developed three-section test: number, applied problem-solving, and abstract reasoning, sensitive to common ASD-related difficulties, e.g., preoccupation with detail and difficulties with inferential reasoning.

To allow effective reduction of cognitive load, a variety of explicit instructional techniques were employed throughout the intervention as shown below.

Reduction of extraneous cognitive load

- Visual supports such as number lines, graphs, and colour-coded cues were used to reduce the extent of mental imagery and make it more explicit.
- Irrelevant textual information or distracting pictures were removed to keep students' attention on the salient features of the task.
- Step-by-step analysis of problem-solving was offered and presented in the form of teacher-directed modeling, followed by guided practice, then independent solution.

Intrinsic cognitive load management

- Problems were tailored to the individual skill level of each student through adaptive difficulty progression—students started with easy problems and advanced only after demonstrating mastery.
- Problems were scaffolded using techniques like task segmentation, prompt questions, and structured problem templates, which allowed students to concentrate on one idea at a time.
- Teachers used dual coding (visual + verbal description) to support abstract mathematical concepts, especially for high visual processing tendency students.

Regulation of relevant cognitive load (learning-directed processing)

- There was regular formative feedback during problem-solving so that thinking and strategy building could be facilitated.
- Students did error analysis tasks to facilitate understanding and correct misconception.
- Sessions included brief review times to cement prior concepts and instill consistency between tasks.

The intervention was spread across 10 weeks, with three 60-minute sessions per week. Teachers who were trained to teach ASD students as well as neuroeducational theory and cognitive load management taught all the sessions. Instructional materials were adjusted weekly by formative assessment and observation of student learning.

To evaluate the impact, data were collected at three time points: before intervention (baseline), after intervention, and one month later to confirm retention. The same instruments were used at each time point to facilitate comparability. Teachers also maintained observational diaries, for instance, attendance, levels of engagement, affect states (e.g., frustration or worry), and on-task behavior, to put performance information into context.

The data were analyzed using ANOVA to compare the working memory capacity, performance on a mathematics test, and subjective cognitive load prior to and following the intervention in both the experimental and control groups. Statistically significant improvement for the experimental group was used as proof that the intervention had been effective in reducing cognitive load and improving mathematical learning outcomes.

RESULTS

Pre-intervention findings indicated that the cognitive load of the experimental group, i.e., ASD students, was much greater than that of the control group. The average score of cognitive loads of the non-interventional ASD students on a scale of 1 to 7 was 4.65, which is an indicator of very high perception of difficulty of math tasks. Comparison with the control group reveals that they achieved a mean of 3.40, which reflects that they self-rated comparatively lower cognitive load. Statistically, the groups were significantly different ($p < 0.01$), reflecting that the students who had ASD rated significantly higher cognitive load before the intervention. After the intervention had been made by replacing math problems with a neuroeducational strategy to reduce cognitive load, the cognitive load of the experimental group decreased dramatically.

Pre-intervention scores revealed that the experimental group (ASD) of students exhibited the highest degree of cognitive load in comparison with the control group. The mean of the ASD group was 4.65 (1–7 scale) on the Cognitive Load Scale for Children (CLS-Child), reflecting high subjective difficulty when performing math activities, compared to 3.40 for the control group ($p < 0.01$). This distinction reinforced the requirement for cognitive load reduction strategies unique to students' neurodiverse learning styles. Acknowledging the susceptibility to self-reporting measures due to the inconsistency in communication and self-knowledge ability of ASD students, due to their variable communication and self-awareness abilities, CLS administration was carefully adapted.

Visual assistance support, such as pictorial Likert scales with affective faces (ranging from "very easy" to "very hard"), and facilitated cues by experienced facilitators were utilized. Minimize paraphrasing of items for individuals with restricted verbal expression or comprehension, symbolic assistance was provided, and repetition approaches were utilized to help individuals understand the items. These adaptations were determined with the assistance of ASD-specialist teachers and neuropsychologists to optimize accessibility and reduce response bias. Moreover, variation along the autism continuum was considered at every point. Communication patterns, attention, and sensory patterns of students were noted and included in administration protocols. For students who were having difficulty responding consistently, additional behavioral markers—withdrawal from the task, physical signs of distress, or requesting help—were triangulated by teachers to offer backup to CLS scores. These adaptations enhanced validity of instrument administration and interpretation with this heterogeneous population of students.

Following the 10-week intervention-based on neuroeducational theory and cognitive load theory, the experimental group's CLS scores dropped significantly to 2.80 ($p < 0.01$), with a significant reduction in perceived task difficulty.

Scores remained low upon one-month follow-up ($M = 2.95$), demonstrating maintenance of the cognitive load improvements. Control condition did not differ from perceived cognitive load (post-intervention $M = 3.45$), suggesting the intervention was the active ingredient in reducing mental effort during math learning. Academically, pre-intervention scores on math tests were significantly lower for the experimental group at a mean of 45.2/100 compared with a mean of 62.3 for the control group. The experimental group rallied significantly after intervention to a mean of 68.4, an increase of 23% ($p < 0.01$), with gains in applied problem-solving activities.

These gains persisted a month later (M = 67.9), whereas the improvement in the control group was minimal and non-significant (from 62.3 to 65.8, then to 64.1).

Working memory capacity was also assessed via the WMTB-C, verbal and visuospatial subtests. Experimental group pre-intervention scores (M = 34.5 verbal; 29.7 visuospatial) were lower than control group (M = 41.2 and 36.5 respectively; $p < 0.01$). Post-intervention, both improved considerably: verbal memory to 39.6, visuospatial to 34.1 ($p < 0.01$), with moderate retention one-month post-testing (M = 38.4 and 33.5 respectively).

These gains are also in line with the hypothesis that reducing extraneous and intrinsic cognitive load not only improves students' short-term mathematics problem-solving skill but also may make underlying cognitive capabilities—such as working memory—stronger that underlie learning in ASD students.

Qualitative parent and teacher data also supported the quantitative results. Teachers documented greater task engagement, reduced frustration, and greater autonomy of math activity in intervention children. Parents reported greater math attitudes and increased incidental practice carried out at home. These results indicate the emotional and behavioral benefits of avoiding cognitive overload through effective, well-planned pedagogical approaches.

CONCLUSIONS

The results illustrate that the neuroeducational intervention, which was designed to reduce cognitive load, acted to enhance several aspects of learning in ASD students. To begin with, the reduction of subjective cognitive load is arguably one of the most applicable results of the research. ASD students exposed to the intervention reported a considerable reduction in the amount of perceived difficulty after exposure to mathematics problems. This was statistically significant and shows that the neuroeducational intervention used was effective in altering the cognitive states that disrupt students with ASD when doing math problems. The result shows a decrease in cognitive load levels from pre-intervention mean score of 4.65 to post-intervention mean score of 2.80, with the improvement being sustained one month later. This change in cognitive load was also accompanied by improvement in experimental group math performance.

The 23% increase in the average score of the experimental group in the math performance test included arithmetic calculations, problem-solving applications, and abstract reasoning is irrefutable evidence that the intervention had a direct influence on student performance. Not only did the ASD students enhance their capacity for basic math problem-solving, but they also enhanced the application of math procedures for solving everyday problems. Most importantly, this finding is significant in that applied problem-solving is an area in which students with ASD have struggled with generalizing information and applying procedures. Analysis of results also shows that the intervention not only affected cognitive load minimimization and performance improvement but also had a positive impact on students with ASD's working memory. Experimental group students showed significant improvement in verbal and even visuospatial working memory, which are extremely important for math problem-solving.

Working memory is one of the most important executive functions of information processing for cognitive tasks, and its improvement in ASD students reinforces the theory that the neuroeducational intervention not only reduced extraneous cognitive load but also augmented internal cognitive abilities for mathematical learning. Intervention impact was also maintained over the long term. A month after intervention, the experimental group of students still exhibited their developed mathematical ability and working memory, a sign that the intervention reflected a stable factor. Stability of effects highlights the need for schooling practice that strives not only for short-term repercussions but seeks long-term differences in the intellectual abilities and academic success of students. Qualitatively, both teacher and parent reports indicated that there was significant improvement in students' motivation and attitude towards mathematics. Teachers reported students to be less anxious and frustrated when facing difficult mathematical activities and capable of learning more actively and effectively.

Parents also reported improvement in the attitude of the students towards mathematics at home, suggesting that the intervention effects were long-term and generalized beyond the classroom.

This qualitative aspect is significant, in that attitude and motivation to learn are key determinants of academic success, especially for students with ASD, who will often exhibit avoidance behaviors when faced by tasks that are frustrating or hard. This study also indicates the need for further research within the arena of neuro-education, and specifically for interventions that cognitively unload the learning of math. Although research has evolved over the years, there are still gaps in the literature as it pertains to more fitting interventions for students with ASD. Findings of this study are a basis for additional examination of a variety of neuroeducational interventions, individualizing interventions to meet the needs of individual students, and rolling out such interventions in regular educational classrooms. The findings of this study are also significant educationally. They suggest that curriculum adaptation strategies, as well as a neuroeducational approach to reducing cognitive load, can be key to improving access and attainment for students with ASD in challenging subjects such as math. Adaptations can allow teachers to turn them to their advantage by building these adaptations into pedagogy for all students regardless of cognitive profile to be able to access learning.

Research will continue in the field of examining the interplay of cognitive load, working memory, and academic performance in students with ASD for a better understanding and fine-tuning interventions that enable them to reach their full potential in the classroom.

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